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MINING AND CRUSHING METHODS AND COSTS AT THE WEST PENN CEMENT CO., LIMESTONE MINE, WEST WINFIELD, PA.

BY

GEORGE A. MORRISON

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MINING AND CRUSHING METHODS AND COSTS AT THE LIMESTONE MINE OF THE WEST PENN CEMENT CO., WEST WINFIELD, PA. [1]

By George A. Morrison [2]

INTRODUCTION

This paper describing the methods of mining and crushing limestone at the West Winfield, Pa., limestone mine of the West Penn Cement Co., is one of a series being prepared by the Bureau of Mines on mining practices, methods, and costs in the various nonmetallic mining districts.

HISTORY

The limestone deposits of western Pennsylvania have been exploited for many years and have been quarried extensively at West Winfield in Winfield Township, which lies in the southeastern corner of Butler County.

At first the limestone was burned in open kilns but later when the demand for furnace stone to flux the iron ores brought into the Pittsburgh district became heavy, the larger sizes of stone were shipped to meet this demand and the smaller sizes were screened out to supply requirements for agricultural lime and railroad ballast.

As the quarries penetrated farther into the hillsides, the removal of overburden became more and more of a problem, until the cost of its removal made the economic quarrying of the stone prohibitive. Underground methods were then tried. This was about 1892, and mining has been going on continuously ever since.

The early methods of mining were naturally crude, the workings were irregular, and hand labor predominated. Later piston drills operated by gas were used until an explosion occurred which was caused by ignition of the gas. The next step was the utilization of steam for the drills and this was

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followed by gas-driven air compressors. From this time on progress in mining practice was steady, and present-day operations are along modern lines.

The West Penn Cement Co. was formed about four years ago to manufacture cement from deposits at West Winfield.

TOPOGRAPHY AND GEOLOGY

The whole property lies in rough rolling hills traversed by streams flowing in a southeasterly direction to the Allegheny River. These streams have cut through the strata and exposed successive horizons of economic value. An important uplift with a northeasterly axis crosses the property. Glacial deposits are scattered over the surface of the hills.

A broad brecciated area, averaging some 1,500 feet across and showing a considerable amount of movement and shifting of the beds, crosses the property in a northeasterly direction. This area contains no workable measures and divides the property into a northern and a southern part.

The accompanying sketch (Fig. 1) shows the sequence of the strata. All mining operations are in the Carboniferous sedimentaries. The Vanport limestone and the underlying shale and sandstone are being mined while the coal that is uncovered by the removal of the shale is left for extraction at a future date.

The limestone stratum, known as the Vanport, is extensively developed throughout western Pennsylvania. It lies about 65 feet below the Lower Kittanning coal measures and is recognized by its fossils (mostly crinoids) and certain physical characteristics as being of marine origin.

On the West Penn property this limestone lies nearly horizontal but in reality it forms the top of an anticline with a north and south axis. The limestone averages nearly 25 feet in thickness on this property and is quite uniform from top to bottom. The only exception to its uniformity is a layer or two near the top which is called the "shell" layer. This layer is denser and more brittle than the underlying stone and often has a layer of shale up to an inch or more in thickness interbedded with it. The bedding planes are well pronounced throughout the deposit and certain layers part well upon blasting. Joint planes and fracture planes run nearly vertical and occasionally break up the stone on shooting, but usually the blasted material is in great masses.

The following analysis is typical of this limestone:

	Per cent
Calcium carbonate.....	90.00
Magnesium carbonate.....	1.00
Silica.....	5.00
Alumina.....	2.50
Ferric oxide.....	1.50

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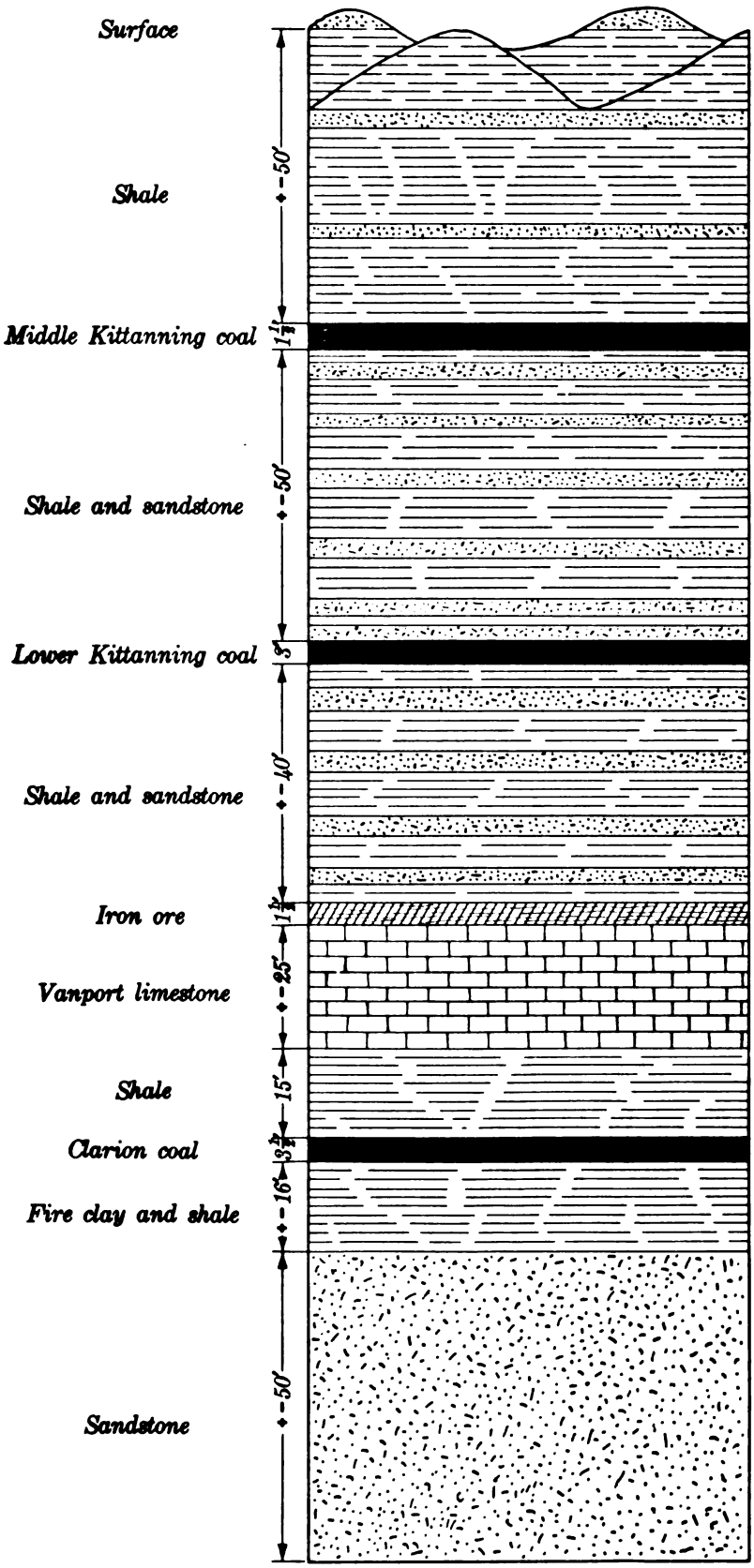

Figure 1.— Vertical section showing the relation of rocks at West Winfield, Pa.

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The limestone rests upon 14 feet of shale from which it parts readily when blasted. This shale in turn rests on 3 1/2 feet of coal (Clarion) which likewise parts readily from the shale.

The shale, which is also mined, is dark gray, of uniform character, and so dense that it must be drilled and blasted for its removal. There are no fossils in this shale, but as it lies between Carboniferous strata -- the limestone above and the coal below -- it is of that age.

A typical analysis of the shale follows:

	Per cent
Silica	56.0
Alumina	19.0
Ferric oxide	8.0
Calcium oxide	.5
Sulphur	3.5
Water	6.8
Volatile	4.0

The Clarion coal which is uncovered by the mining of the shale is a fair grade of soft coal and has the following analysis:

	Per cent
Volatile	33 to 44
Ash	13 to 6
Sulphur	2 to 1
Fixed carbon	52
B.t.u.	12,600

Lying directly below this coal are from 10 to 16 feet of fire clay (known as the Clarion). This is used by the Pennsylvania Clay Products Co. and has the following analysis:

	Per cent
Silica	57.22
Alumina	34.17
Ferric oxide	.24
Calcium oxide	1.17
Magnesium oxide	.49
Water	5.82

While probably too high in calcium and magnesium for making fire brick, this clay is desirable for tile, sewer pipe, etc.

Immediately below the fire clay is the Clarion sandstone. This deposit is 50 feet thick, very uniform in character, and has a high silica content. The following is an average analysis:

	Per cent
Silica	98.28
Alumina	.35
Ferric oxide	.61

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The only impurities are occasional iron spots and knife-edge seams of interbedded coal.

Overlying the limestone are repeated layers of shale and sandstone, which are of no economic value. Among these impure and weak measures are two coal beds. The lowest of these, the Lower Kittanning, is about 3 feet thick and may be of value some day.

EXPLORATION

The extensive quarrying of the limestone in the early days proved the uniformity of the Vanport limestone in the western Pennsylvania district. The numerous well drill holes driven on this property quite completely outlined the deposit on the company's land. The drill holes were primarily for gas and oil which is found at a depth of some 2,000 feet. Many of these wells are producing at present and must be avoided in mining.

Recently holes have been drilled to determine the extent of the brecciated zone already mentioned. These holes, 5 1/2 inches in diameter, are from 100 to 300 feet in depth and cost 75 cents to $2 per foot, depending upon accessibility of their location, depth, etc.

In some places the limestone outcrops, but for the most part it is covered with a thick mantle of shale, sandstone, and soil.

The uniformity of the stone as to its chemical analysis, physical characteristics, and extent simplifies the mining of the deposit.

SAMPLING

Few mine samples are necessary but samples are taken hourly and analyzed at the cement plant laboratory and careful check is kept on all ingredients as they are ground into slurry. Slight variations are corrected to maintain the desired analysis of the mix going into the cement.

A considerable amount of the stone mined is sold for commercial purposes. This is marketed on a basis of screen analysis specified by the purchaser. These analyses are made at the mine so the product may be kept up to the specified requirements.

CHOICE OF MINING METHODS

The flat-lying strata penetrate from the valley walls into steeply rising hills until the limestone measures often have an overburden of 200 or 300 feet. In the early quarrying the outcropping stone was first worked out. Afterwards stripping was carried on until its cost prohibited further operations by this method.

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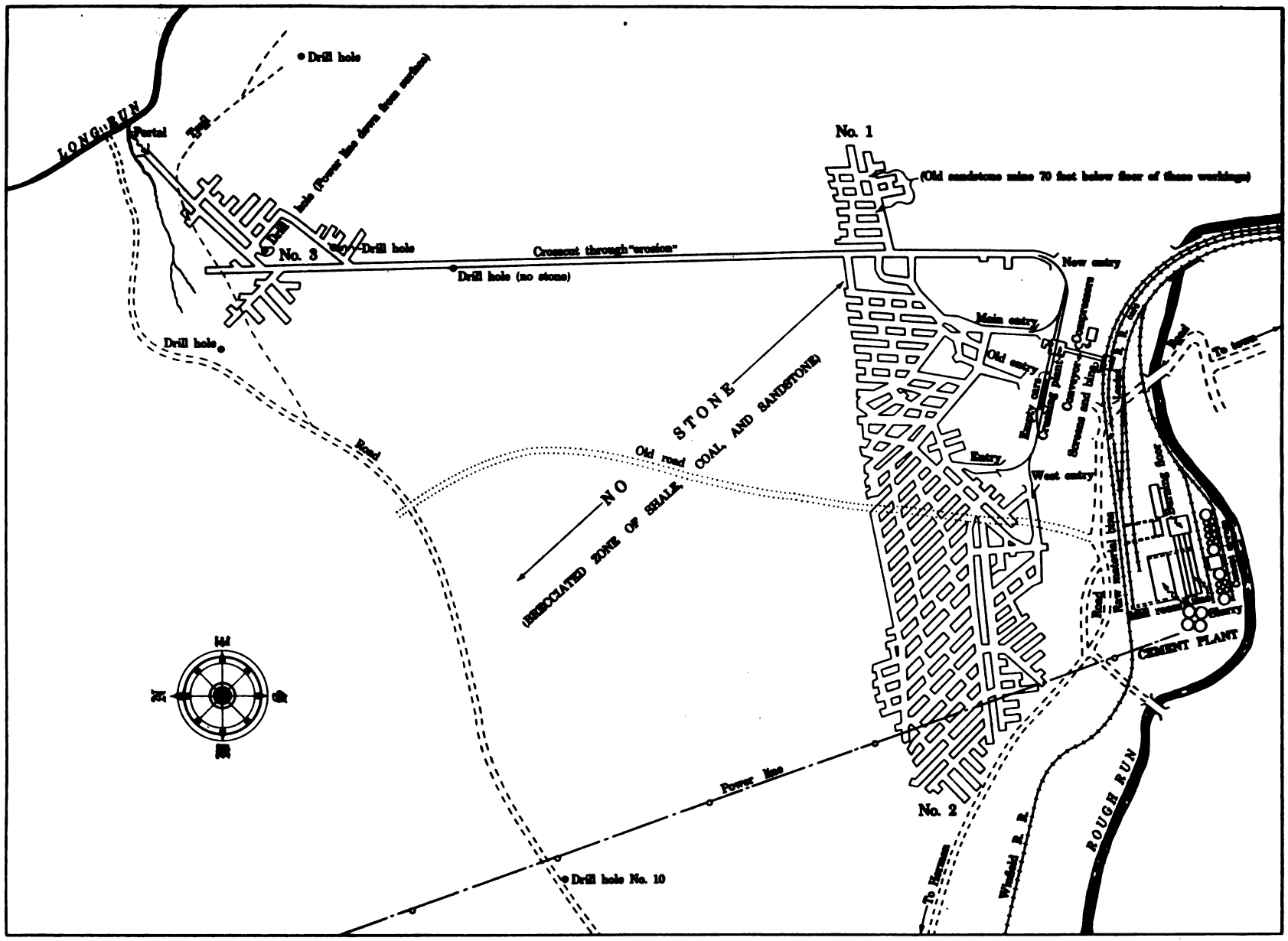

Figure 2.—Plan of mine workings

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Then openings were driven into the hills for removing the stone without stripping. Some irregular pillars were left to support the roof. Soon afterwards a single-entry system was adopted, with rooms running off at regular intervals to either side. Later came the installation of the present double-entry system with rooms driven to the left off the left-hand entry and to the right off the right-hand. This system of rooms and entries with ribs left between them for support is the present practice.

The entries and rooms are 30 feet wide, and 25-foot pillars are left between. Openings 30 feet wide are put through the rib pillars every 100 feet or so.

Two or three layers of stone are left in place in the roof of these rooms and entries to support the weak overburden of shale and sandstone. The thickness of roof layers left for support varies from 3 to 5 feet, depending upon the thickness of the overburden at that point.

The floor of the workings is the top of the shale measures. The height of the workings is determined by a uniform parting layer usually occurring 19 feet above the floor of the limestone. This height is quite constant but in a few places in the mine it drops to 10 or 12 feet. The high, wide openings of the underground workings stand up well with little or no timbering.

The accompanying map (Fig. 2) shows a plan of the mine workings in relation to the surface layout.

During the busy season a daily production of 2,000 tons of limestone and about 200 tons of shale is maintained. There is no waste, as all of the tonnage broken is either screened and sold to the commercial stone trade or shipped to the cement plant.

DRILLING AND BLASTING

The method of extracting the stone is a breast-stoping system whereby the opening is advanced its full height in one cycle of operations. The width of 30 feet is taken out in a series of "V" cuts driven into the face. The center cut takes out a wedge-shaped piece to a depth of about 8 feet. Then by setting up the drill in the notch formed by the shooting of the "V" cut, holes are drilled to meet other sets of holes drilled from the original face along the rib. These are called the "angle cuts" and two of them are required to bring the full room width of 30 feet for an advance of about 8 feet.

The drill is again set up but this time on the muck pile resulting from the previous blast, and the cycle is repeated again and again, each time from a higher muck pile, until the last set-up is 12 feet or more above the floor.

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The drilling is arranged so that a set of four holes fanned from one set-up will meet four holes from another set-up at right angles. The drill runner lays out the holes by using a powder box as a square and a drill-steel for a straight edge so that he can determine where to start the companion holes, their angle to the face, and their depth.

The vertical arrangement of holes is also fan shaped and drilled so four holes from one set-up will meet four holes drilled from another set-up. The drilling is done so the top holes come together about a foot below the desired roof and the bottom holes about the same distance above the shale floor. The vertical distance between the apexes of the top holes and those of the bottom holes is 15 feet, and a break 17 feet high results when the holes are blasted.

The accompanying sketches (Fig. 3) show the drill round in plan and section.

After three or four rounds the face has been advanced about 30 feet and a stoper drill is set up on top of the broken stone pile to drill 2-foot vertical holes (Fig. 3) into the roof on 6-foot centers. These holes are blasted in units of 30 to 36 holes, and the room, then containing about 2,000 tons of broken stone, is ready for the power shovel.

In drifting, 3 1/2-inch hammer drills are used mounted on tripods, and all holes are drilled wet. Air at 100 pounds pressure at the compressors delivers about 80 pounds at the drills. Line oilers and a good grade of liquid grease are used on all machines.

The drill steel is 1 1/4-inch hollow round and is fitted with lugs on shanks. The starter has a 2 1/8-inch cross bit of the McLellan type and 1/8-inch decrease in the gage is made on each 30-inch change in the steel length so the bottoming steel (13 ft. 6 in.) has a 1 5/8-inch bit.

A machine will average 165 feet of holes per drill shift making four setups and using from 6 to 9 bits. The drilling speed of the machines is 9 inches per minute, and the steel is actually cutting rock 37 per cent of the time. The balance of the drillers' time is consumed in rigging in and out, changing set-ups and steel, blowing out finished holes, and mucking out for set-ups. A helper is used on each machine, as the long steel must be bent to get it into the hole in the narrow "V" cut.

The depth of holes varies from 8 to 13 feet, depending upon the condition of the face. All drill holes are loaded by blasters on a night shift and are fired by blasting machines.

A special pulverant dynamite of 35 per cent strength is used in 1 1/2 by 8 inch cartridges for all face shots. Another type of dynamite of 37 per cent strength and less mealy is made up in 1 1/4 by 8 inch cartridges for use in blockholes and stoper work. Little secondary blasting is required,

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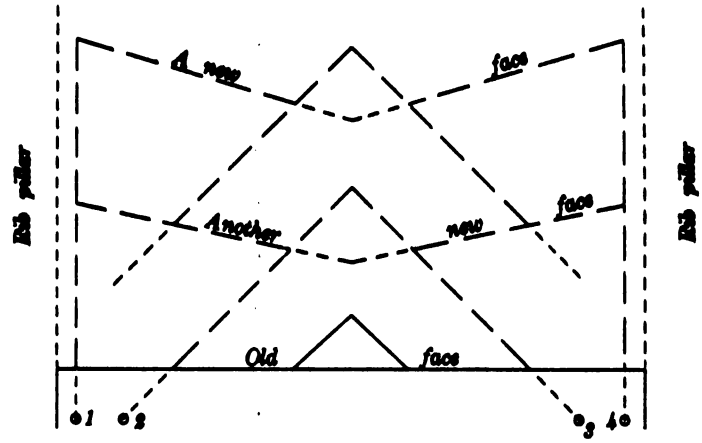
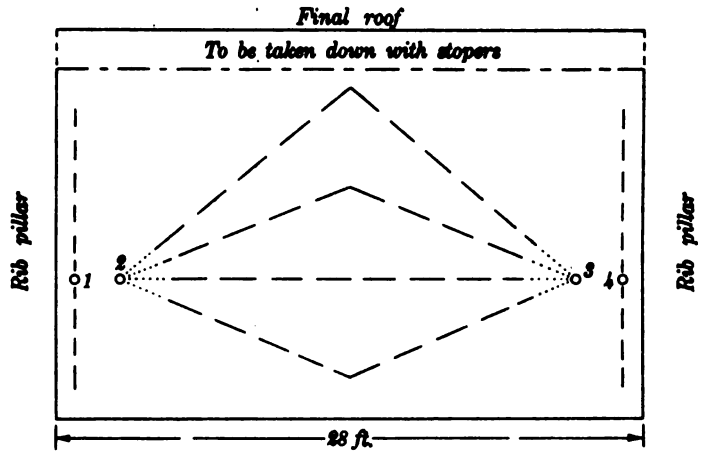
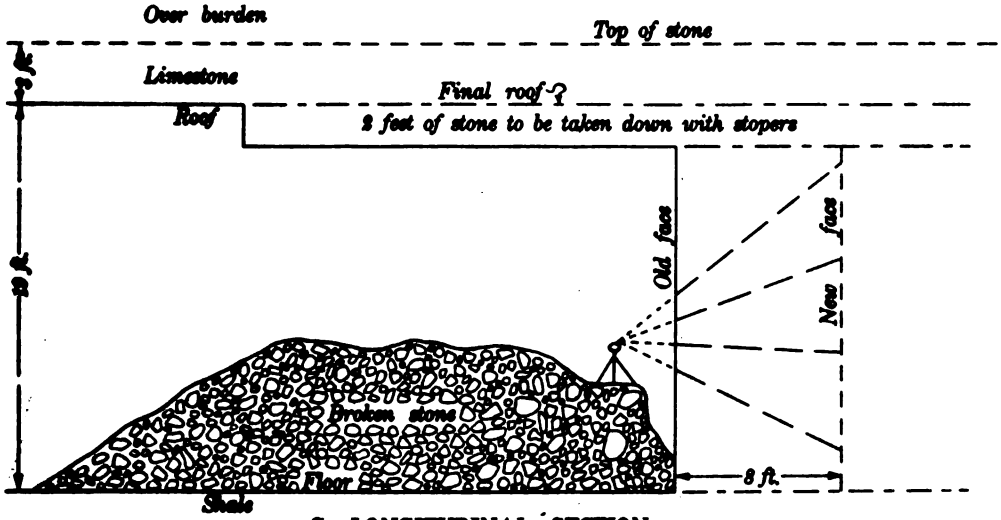


A. CROSS SECTION PLAN



B. VERTICAL CROSS SECTION



C. LONGITUDINAL SECTION

Figure 3. – Drill round

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as many face holes are intentionally overloaded so the blasted material is kicked as far back into the room as possible to insure its being filled with broken stone before the shovel is moved in.

All holes are tamped with at least three cartridges of tamping made up by the blasters. No. 6 electric detonators with 8 and 10 foot copper lead wires are used. Three blasters working on a night shift prepare the tamping, make up their primers, and load and shoot all holes. No. 14 insulated copper wire is carried on fixed supports to all faces being worked from locations convenient for the blasting stations. No. 20 annunciating wire is used to connect the main lead wires to the detonator wires.

An average of 0.6 pound of dynamite is required per ton of stone produced. This includes all secondary shooting and powder used for any other purpose.

LOADING THE STONE

The broken stone is loaded by means of three full-revolving electric shovels which are mounted on caterpillars. These shovels are of 5/8, 1, and 1 1/4 cubic yards capacity, respectively. The 5/8 cubic yard shovel is several years old and inefficient but the other two shovels are of modern design and have proved very efficient. Each of these newer machines is fitted with a 15-foot boom and a 10-foot dipper stick. The first two shovels use 250-volt current supplied from the trolley lines, and the last and largest shovel uses alternating current at 440 volts which is converted to 250 volts (d.c.) by means of a motor generator set mounted on the shovel.

Twenty three hundred volt alternating current is brought into the mine through a 12-inch drill hole 140 feet deep. This current is stepped down at the bottom of the hole to 440 volts before being carried in well-insulated triple-conductor cable through the mine to suitable taps for connecting flexible feed wires to the shovel. The largest shovel has proved especially satisfactory and has repeatedly loaded over 1,000 tons of stone in a 10-hour shift. In 1930 it averaged 700 tons per shift. An average for the three shovels combined is 1,500 tons per shift. The shovels clean up well along the ribs and at the faces. Each is served by a trolley locomotive equipped with a gathering reel and running on double track in each entry and room. These locomotives keep an empty car at the shovel on one track while replacing a loaded car with an empty one on the other track. Enough empty cars are kept in the string at the shovels so, as is often the case, more than one car can be loaded before requiring replacement with empties. When a train of 7 to 12 cars has been loaded, it is hauled away to the crusher and an empty train is moved up to the shovel. In the meantime the shovel has from two to four empty cars to load which were left by the locomotive before making its trip.

Table 6 shows the loading data for the first six months of 1930.

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Hand loaders are employed at a contract price of $0.215 per ton to clean up faces and clean out rooms where track is to be laid up to the blasted pile so the power shovels can work on a thick pile of broken stone. At present the hand-loaded tonnage amounts to about 17 per cent of the total tonnage. Later another power shovel will be put to work and much of this hand labor will be eliminated.

A typical shovel crew consists of the following men:

Drillers	2 - 4
Drillers' helpers.....	2 - 4
Scalers and blasters.....	2 - 3
Locomotive runners.....	1 - 2
Locomotive-runners' helpers	1 - 2
Trackmen.....	2 - 4
Shovel runners.....	1 - 1
Shovel-runners' helpers..	1 - 1
Total.....	12 - 21

TRANSPORTATION

Seven-ton trolley locomotives are used, and at present there are four on the property. One locomotive is used for each shovel, and the fourth is used to haul to the crusher from a remote part of the mine. At present the locomotives gathering for two of the shovels also haul to the crusher.

These locomotives have 22-inch wheels with a 4-inch face, a 44-inch wheel base and are 13 feet long over-all. They are powered with two 120-ampere, 250-volt motors, are driven by worm-gears, and have a draw-bar pull of 3,700 pounds. Previously horses were used for gathering but in 1930 their use was entirely discontinued.

The mine cars (Fig. 4) are a solid-body type dumped by means of a rotary car-dumper, which is actuated by compressed air. These 135 cubic feet capacity cars have 4-inch axles, with outside journal boxes mounted on 8-inch Hyatt roller bearings and are equipped with four-wheel brakes. The car is 12 feet long by 6 feet wide and stands 46 inches above the track. The wheels are 16-inch chilled iron having a face of 4 inches and a wheel base of 38 inches. One wheel is tight on each axle. The car bottom is of 3-inch oak plank between 3/8-inch sheet-iron plates. The cars weigh nearly 4 tons each and carry an average load of 8 tons. The couplings are swivel-hitchings of heavy design, so a train can be dumped at the crusher without uncoupling the cars.

Trains of from 8 to 12 cars traverse a circuit so arranged that they are always moving in one direction.

Tracks of 36-inch gage are laid with 40-pound rails on 5 by 6 inch by 5 foot oak ties on 2 1/2 foot centers. Every fourth tie is a steel one of heavy design having fixed gage clamps. Curves are of 70-foot radius. No. 3 frogs are used in the switches with 5-foot switch points and 7 to 9 foot

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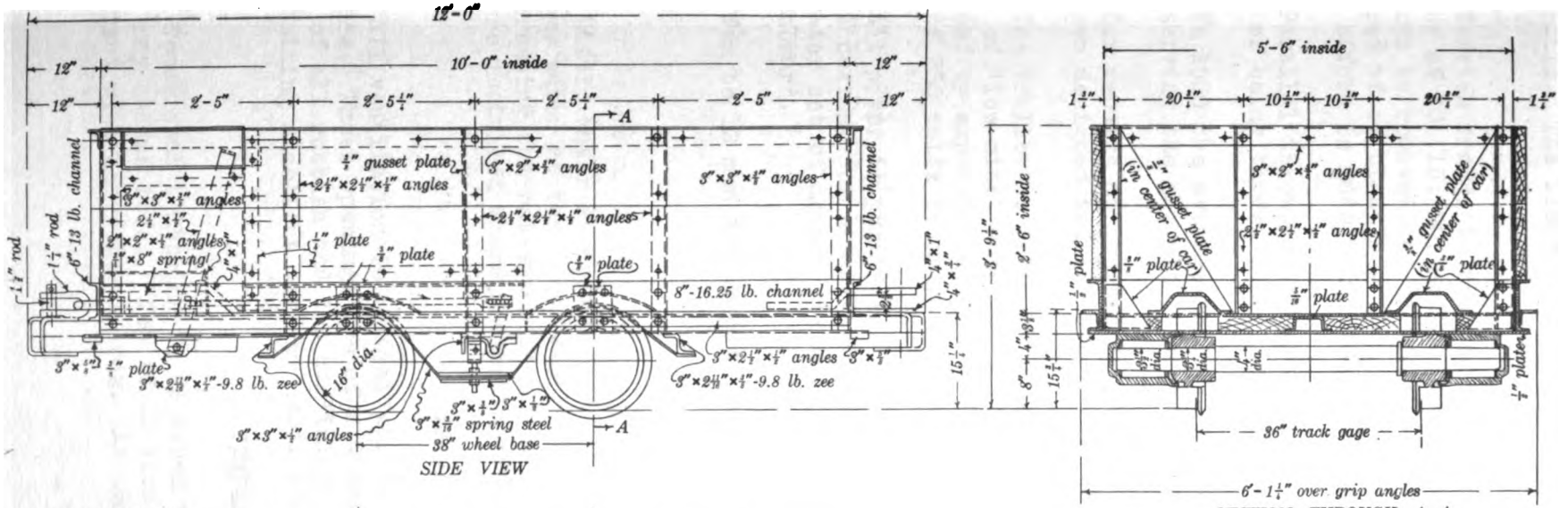

NOTE:

Center floor	2¼" oak plank
Outside	2¼" oak plank
Sides and ends	1¼" oak plank
Bumper filler	2¼" oak plank
Top floor lining	¼" plate
Bottom floor lining	¼" plate
Side and end lining	¼" plate
Wheel hoods	⅜" plate
Brake pockets	¼" plate
Bumpers	½" plate

Wheels, single plate, 16-in. diameter
Hyatt roller bearings 3¼"×7"
Capacity, level full, 135 cubic feet

Figure 4.—Mine car of the West Penn Cement Co.

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lead rails. The floors are usually smooth and level but occasional rolls occur.

Service tracks to the working faces are of a temporary nature and are made up of 10, 15, 20, and 30 foot sections mounted on light steel ties so they can be removed and carried to another working face or else relaid when required after blasting. Rock ballast is used on all permanent track, and every effort is made to maintain all such track in the best condition.

Parallel throw-switch stands are used to avoid the possibility of the operator being thrown under passing cars when throwing a switch.

In 1930 the average haul (loaded) was about 3/4 of a mile and the 75 cars serving the shovels averaged five trips per shift.

Car repairs at present are mostly due to broken wheels. A new wheel has been designed and its use is expected to reduce this breakage greatly.

The trolley is a "0000" wire suspended 8 1/2 feet above the track by means of "low-mine" suspension insulators and pipe trusses fastened into the roof by expansion sleeves. By careful bonding and crossbonding a current of 250 volts is maintained throughout the mine.

All power is purchased, at 2,300 volts and transformed to 250 volts direct current for haulage in the mine by means of a 150-kilowatt motor-generator set of modern design which is in turn served by an automatic switchboard.

Ten to 12 men are engaged in serving the shovels and maintaining track.

DRAINAGE

Little water is encountered, but in certain sections of the mine there is some water at the faces and it is a great hindrance in laying track and in screening the wet stone in the crushing plant. Small pumps operated by air are installed where necessary and moved from place to place as required.

VENTILATION

All ventilation is natural and is obtained by frequent openings to the surface. These openings are of a large cross section. The constant clearing away of all rubbish and the confining of blasting to one shift contribute to maintaining excellent working conditions.

TIMBERING

Occasional timbering is required to support certain layers in the roof that may become loose. Ten to 12 inch posts cut from the company's property are used with heavy headboards. At some places in the mine the openings to

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the surface pierce roof layers so badly leached that they have no strength. In such places drift sets with heavy lagging are required.

SHALE MINING

The floor of the limestone is shale which extends from about 14 feet to a 42-inch bed of coal. This shale is mined out of rooms from which the stone has been extracted.

To reach this level at the top of the coal a track on a 7 degree slope is carried down from the old room floor at one place in the mine. The track is thereafter continued on the top of the coal from room to room, going through ribs as they are encountered at points where holes have previously been cut in mining the limestone.

The shale is broken with sinker drills which drill 12-foot holes on 6-foot centers in the old room floors. About 250 tons of shale are required per day and this is broken by two men who do all drilling and blasting and look after the track. The shale loading is all done by hand. The loaders are paid on contract at a rate of $0.215 per ton.

The coal uncovered by mining the shale is left in place for mining at some future date when it may be required. A considerable tonnage of this coal has already been uncovered.

CRUSHING PLANT

Car-Dumper.- The loaded cars, delivered by locomotives in trains of from 8 to 12, are set on the loaded-car track at the crushing plant. An electrically driven car-puller, consisting of a standard hoist handling a continuous cable through sheaves along this track, hauls the trains in over the car scales and into the car dumper, which is set on a 1 1/2 per cent slope. The cars are completely emptied without being uncoupled by being given a half turn in the dumper cradle, which is revolved by means of compressed air. Two men serve the dumper and also hook the trains and look after the crushers below. The empty cars drift down the empty-car track to be picked up by the locomotive that brought in the loads and which has by-passed the crusher building. The return trip into the mine is on a different track than that over which the loads came out and a circular path of traffic is thereby maintained over which the trains are moving only in one direction.

The dumped stone goes directly into a 30-inch gyratory crusher with its discharge opening set at 4 inches and which is belt driven by a 125-hp. motor. The product from this primary crusher goes over a No. 9 live-roll grizzly with 2 3/4-inch openings which is powered by a 10-hp. motor driving through sprockets and chain.

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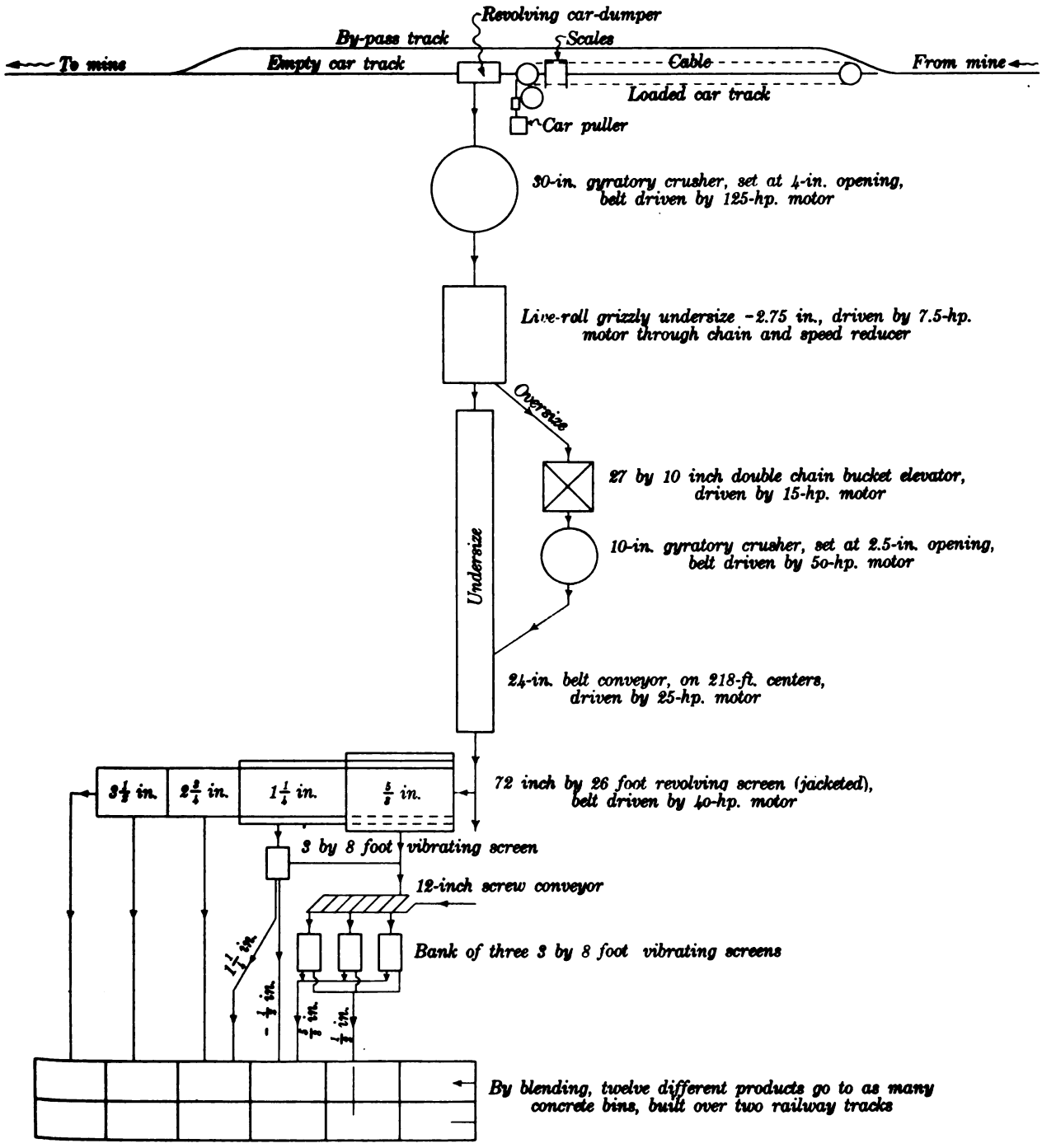
Revolving car-dumper
By-pass track
Scales
To mine
Empty car track
Cable
From mine
Loaded car track
Car puller
30-in. gyratory crusher, set at 4-in. opening, belt driven by 125-hp. motor
Live-roll grizzly undersize -2.75 in., driven by 7.5-hp. motor through chain and speed reducer
Oversize
27 by 10 inch double chain bucket elevator, driven by 15-hp. motor
10-in. gyratory crusher, set at 2.5-in. opening, belt driven by 50-hp. motor
Undersize
24-in. belt conveyor, on 218-ft. centers, driven by 25-hp. motor
3½ in.
2¾ in.
1¼ in.
⅝ in.
72 inch by 26 foot revolving screen (jacketed), belt driven by 40-hp. motor
3 by 8 foot vibrating screen
12-inch screw conveyor
Bank of three 3 by 8 foot vibrating screens
1¼ in.
- ¼ in.
⅝ in.
¼ in.
By blending, twelve different products go to as many concrete bins, built over two railway tracks

Figure 5. — Flow sheet of crushing plant

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From the grizzly the oversize is lifted by means of a 40-foot elevator equipped with close-connected steel buckets on double chains, to a 10-inch gyratory crusher which is set at a 2-inch discharge opening and is belt-driven by a 40-hp. motor. The discharge from the crusher joins the undersize from the grizzly and is delivered onto a 24-inch conveyor belt 218 feet long and inclined 3 1/8 inches per foot which conveys the stone to the top of the screen room.

In the screen room is a double-jacketed revolving screen 72 inches in diameter and 26 feet long, mounted at a slope of 1 1/4 inches to the foot, over concrete bins. The holes in the revolving screen are round and are punched in 3/8 inch plate. The first jacket is also made of punched plate but the second one is of woven wire with 5/8-inch holes. All vibrator screens are also of wire screening with square holes. The products of the revolving screen, after the proper blending on vibrating screens, fall into 12 concrete bins which hold about 150 tons each. The bins feed through wide-mouthed gates, operated by hand, into railway cars standing on the double railway tracks immediately beneath.

The delivery of the product carried by the conveyor from the crushers is arranged so that, by means of chutes and gates, stone for the cement plant can be delivered directly to bins without having to go through the revolving screen. The screened products are blended as required by the specifications of the trade for road material and concrete aggregate.

An 18-inch apron conveyor traverses one side of the bins and elevates material from any bin to a mechanically-vibrated screen which is drenched with water from numerous nozzles under high pressure. This washed material is drained while passing through metal spouts into the railway cars below.

Finished stone for the cement plant is delivered in hopper-bottomed railroad cars which are drawn into the unloading-tunnels at the plant, or else have their loads stocked in convenient piles to be reclaimed by locomotive cranes as required.

Truck haulage from all bins is provided by conveniently operated chutes. Figure 5 is a flow sheet of the plant.

Table 1 gives a summary of crushing data for the first eight months of 1930.

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Table 1. - Crushing Plant Operating Data, First Eight Months of 1930.

Month	Tons	Total hours	Delays in hours due to				
			No stone	No railroad cars	Big pieces	Miscel-laneous	Total
January	33,800	195	16	1	3.5	3	23.5
February	26,400	144	15	.5	1	4	20.5
March	37,000	200	24	1.5	3	6	34.5
April	23,650	152	32.5	--	3.5	.5	36.5
May	42,500	250	30.5	--	5	2	37.5
June	51,700	270	25	--	3	3	31
July	48,200	231	32	1	4	5	42
August	51,975	262	40	--	6.5	1.5	48
Total	315,225	1,704	215	4	29.5	25	273.5
Percentage of delays	--	--	78.5	1.5	11	9	100

Percentage of lost time - 16
Average number of tons per hour - 186
Average number of tons per hour (if no lost time) - - - - - - - - - - - - - 220

Note:

"No stone" means that the dumper was idle because of no loaded mine cars to dump.
"No railroad cars" means that there was a shortage of these cars.
"Big pieces" indicates that the crusher was plugged or arched over.
Under "Miscellaneous" are included delays for oiling, repairs, or cars with broken wheels.
The tonnage is for stone and shale. The shale is much slower in crushing.
The plant capacity can be assumed to be 250 tons per hour, and the actual production 225 tons.

In the three years this plant has operated, no renewals have been required by the crushers (except for some bottom plates in the 30-inch gyratory), conveyor, or revolving screen. Chutes have had to be relined and patched, however. The screens on the vibrators last about six months, and the drive belts on them are likely to whip out at the fastenings in a few months.

The flow sheet (Fig. 5) shows that the undersize through the 5/8 inch revolving screen passes to a bank of three vibrating screens. A smaller number of vibrators might do the work but it was considered possible that 1/8-inch screens might be used on them, and as the stone from the mine is often damp it is necessary to carry a thin bed on these machines to insure proper sizing.

Table 2 shows screen analyses of the various products.

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The crushing plant is operated primarily to supply the cement plant with raw material and the screening plant to supply surplus production to the commercial stone trade. The requirements as to size of commercial stone vary and the tonnage demand is also erratic. No anticipation of the sizes and tonnage required can be made definitely. Since space for stock piling is limited around the plant and the demand for the products fluctuates, it is often necessary to put the whole daily production over the screens to produce the required tonnage of some certain size or sizes.

Table 3 lists some of the products sold and their specifications. By means of spouting between screens and bins, mixtures are made so many combinations can be turned out for shipment.

PER CENT EXTRACTION

As there is no concentration, the crushing plant delivers the same tonnage it receives.

The mining recovery at present is 55 per cent. The remaining 45 per cent can be recovered later by removing pillars on a retreating system from any places where the surface is of so little value that subsidence is not objectionable.

The cement plant consumes two-thirds of the mine output and the balance is sold to the trade as commercial stone.

EMPLOYEE'S PAY SYSTEM

The mine is operated on a six-day week basis of 8 or 10 hours daily, depending upon the tonnage required. Due to a fluctuating market, the working season varies somewhat, but 10 months is about the average year.

Except for about 18 per cent of the total, all labor is paid on an hourly basis, and wages vary from 45 to 80 cents per hour. The shale and some of the stone is loaded by hand on contract at a rate of $0.215 per ton, and it is this labor that accounts for the 18 per cent exception noted above.

SAFETY METHODS, ETC.

Well-equipped first-aid cabinets are kept at various places throughout the mine and crushing plant. Each locomotive and shovel also carries a kit.

The mine is divided into three divisions, each under a separate boss. These divisions compete with each other for quantity of production and the least number of accidents.

Three first-aid teams are kept in training, one team for each division of the mine.

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In 1929 the whole force was given a course in first-aid under the direction of a representative of the Bureau of Mines.

Careful scaling of the roofs, well-planned preparation for shots, adequate lighting of workings, cleaning up openings and keeping passageways free from stone, etc., maintaining equipment in the best repair, and efficient workmen who think of the possibilities of an accident as well as efficiencies all aid in maintaining the low accident rate the company enjoys.

EFFICIENCIES AND COSTS

Tables 4, 5, 6, 7, and 8 give various statistics of performance. Figure 6 is an organization chart.

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Table 2. - Screen Analyses

	Primary crusher				Secondary crusher				Main screen		5/8-inch screen	
	Mine run (feed)		Product		Feed		Product		Feed		Feed	
Percentage of total	100		100		35.75		35.75		100		17	
Tons per hour	225		225		80.50		80.50		225		38.25	
	Per cent	Tons	Per cent	Tons	Per cent	Tons	Per cent	Tons	Per cent	Tons	Per cent	Tons
Plus 6-inch	25	56.25	0	--	--	--	--	--	--	--	--	--
Minus 6 plus 3½-inch	15	33.75	16	13.50	[1]71.5	57.56	[1]5.8	4.67	2.0	4.50	--	--
Minus 3½ plus 2¾-inch	19	42.75	32	72.0	17.5	14.09	[1]33.0	26.57	12.0	27.0	--	--
Minus 2¾ plus 2-inch	12	27.00	14.8	33.3	8.5	6.84	32.1	25.84	25.0	56.25	--	--
Minus 2 plus 1¼-inch	10	22.50	18.0	40.50	1.5	1.21	21.5	17.30	26.0	58.50	--	--
Minus 1¼ plus 5/8-inch	10	22.50	[2]15.0	33.75	.5	.40	3.8	3.06	18.0	40.50	--	--
Minus 5/8 plus 3/8-inch	2	4.50	3.0	6.75	--	--	1.0	.80	4.0	9.00	21.2	8.10
Minus 3/8 plus 1/8-inch	3	6.75	[2]5.6	12.60	.25	.20	1.4	1.13	6.5	14.625	38.8	14.85
Minus 1/8-inch	4	9.00	[2]5.6	12.60	.25	.20	1.4	1.13	6.5	14.625	[2]40.0	15.30
	100	225	100	225	100	80.5	100	80.5	100	225	100	38.25

1 Flat tabular pieces.
2 Decrease in percentage due mostly to spalling and wearing down in chutes.

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Table 3. - Screen analyses of various crushing-plant products.

Material	Percentage through												
	100 mesh	1/8 inch	1/4 inch	3/8 inch	5/8 inch	1 inch	1-1/4 inch	1-1/2 inch	2 inch	2-1/2 inch	2-3/4 inch	3-1/2 inch	4 inch
A	0 - 25	--	--	-	100	-	-	-	-	-	--	-	-
B	-	0 - 10	0 - 20	-	100	-	-	-	-	-	--	-	-
C	-	-	-	0 - 8	10 - 40	-	95 - 100	100	-	-	-	-	-
D	-	-	-	0 - 10	0 - 50	95 - 100	100	-	-	-	-	-	-
E	-	-	-	0 - 8	5 - 20	-	30 - 65	-	-	95 - 100	100	-	-
F	-	-	-	-	-	-	0 - 15	-	30 - 65	95 - 100	100	-	-
G	-	-	-	-	-	-	0 - 10	-	-	25 - 50	-	90 - 100	100
H	-	-	-	0 - 8	0 - 30	-	95 - 100	100	-	-	-	-	-
I	-	-	-	0 - 8	0 - 15	-	30 - 65	-	-	95 - 100	100	-	-
J	-	-	-	-	-	-	0 - 15	-	-	30 - 65	-	95 - 100	100
K	-	0 - 3	0 - 10	25 - 40	Pass ½"	-	-	-	-	-	-	-	-
				25 - 40	" ¾"	25 - 40	90 - 100	100	-	-	-	-	-
L	-	-	-	0 - 8	0 - 15	-	30 - 65	-	-	95 - 100	100	-	-
M	8 - 12	-	-	-	95 - 100	-	-	-	-	-	-	-	-
N	-	-	0 - 5	-	0 - 25	-	-	75 - 95	100	-	-	-	-
O	-	-	-	0 - 8	0 - 15	-	30 - 65	-	95 - 100	100	-	-	-
P	-	-	95 - 100	100	-	-	-	-	-	-	-	-	-

Note:- These products are not made at the same time, but the plant may be called upon at any time to make a number of them. They are made by blending in chutes and bins, so that the proper mixture goes into the railroad cars.

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Table 4. - Drilling data, January 1st to December 1st, 1929.

Periods by quarters	First	Second	Third	Fourth	Total
Drill shifts (drifters only)	207	525	607	266	1,606
Feet of drilling (drifters only)	29,874	84,823	102,000	42,526	259,220
Average feet drilled per drill shift	145	161	168	160	160
Steel used (total number)	1,315	4,584	5,609	2,420	13,928
Steel used per drill shift (average number)	6.3	8.8	9.5	9	8.7
Percent of steel broken	5.3	6.0	7.5	4.7	6.3

Total shifts, all drills	[1]2,283
Total repairs, all drills (including tanks, tripods, etc.)	$2,107
Repairs per drill shift	$0.92
Tons produced	388,285
Feet drilled per ton	0.67
Tons per drill shift (1606 plus stoper 425 equals 2031 shifts)	190
Steel-sharpener shifts	250
Steel-sharpener shifts per drill shift	0.11
Steel used per drill shift (average number)	8.7
Steel produced per sharpener shift	55
Repairs per sharpener shift	$0.60
Drill repairs per ton produced, 1929	$0.0054
Drill repairs per ton produced, 1928	.0053

[1]This figure includes 252 drill shifts employed in block-holing or secondary drilling.

Note: The steel in 1 1/4 and 7/8 inch sizes contained 0.87 per cent carbon. Fifty per cent of the breakage is in the 7/8-inch steel used in stoper machines.

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Table 5. - Transportation data, January 1st to July 1st, 1930.

Tons hauled, stone and shale	212,116
Tons hauled, stone and shale (including double haul in gathering	292,100
Average length of haul, feet (loaded)	2,359
Ton-miles hauled	130,500

Costs (gathering included)	Per cent	Per ton produced	Per ton double-hauled	Per ton-mile
Locomotives:				
Operating labor		0.027	0.0196	0.0438
Repair labor		.004	.0038	.0062
Operating supplies		.001	.0007	.0015
Repair supplies		.003	.0025	.0055
Power		.003	.0021	.0047
Total locomotives	34	.038	.0287	.0617
Trolley:				
Labor		.004	.0032	.0071
Supplies		.002	.0016	.0035
Total trolley	5	.006	.0048	.0106
Cars:				
Labor		.005	.0038	.0085
Supplies		.006	.0041	.0092
Total cars	10	.011	.0079	.0177
Track:				
Labor		.038	.0275	.0609
Supplies		.015	.0111	.0247
Total track	48	.053	.0386	.0856
Livestock: Labor and supplies	3	.004	.0032	.0068
Total transportation	100	.112	.0832	.1824

Note: The average tons per trip to the crusher is 64.
Gathering requires many trips of but small tonnage; making up trains and placing empties. The average car load is 8 tons.

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Table 6. - Power shovel data, January 1st to July 1st, 1930.

Shovel number	No. 1		No. 2		No. 3		Totals and averages	
Total tons loaded	61,000.		72,500.		26,700.		160,200.	
Tons loaded daily (10 hrs.)	555.		702.		342.		550.	
Tons loaded per car	7.75		7.73		8.15		7.80	
Percentage of time operating	84.		85.		74.		83.	
Percentage of lost time	16.		15.		26.		17.	
Loading cost in dollars per ton:								
Operating labor	0.028		0.028		0.047		0.037	
Repair labor	.005		.006		.014		.007	
Operating supplies	.002		—		--		.001	
Repair supplies	.008		.007		.015		.008	
Power	.004		.003		.006		.004	
Total cost	.048		.044		.082		.052	
Operating data:	Per-cent	Minutes per shift	Per-cent	Minutes per shift	Per-cent	Minutes per shift	Per-cent	Minutes per shift
Delays due to -								
Mechanical trouble	11)	25	20)	24	30)	59	19)	31
Electrical trouble	15)		7)		8)		10)	
Moving shovel	11	11	20	18	16	25	17	17
Track-laying, etc.	26)		20)		9)		21)	
No empties	12)		16)		20)		15)	
Locomotives	5)	60	4)	48	2)	72	4)	54
Wrecks	12)		8)		10)		10)	
Bench (hard digging)	8)		1)		5)		4)	
Total delays	100	96	100	90	100	156	100	102
Maximum hourly production (tons)	75.		105.		45.		79.	
Average hourly production (tons)	55.5		70.2		34.2		55.0	
Efficiency: Average divided by maximum (per cent)	74½		67.		76.		70.	

Note: All shovels are electric, full-revolving and served in the same manner. No. 1 shovel is of 1 cu. yd. Dipper capacity. No. 2 shovel is of 1¼ cu. yd. Dipper capacity. No. 3 shovel is of 5/8 cu. yd. Dipper capacity.

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Table 7. - Summary of costs in units of labor, power, and supplies.

	Mining			Crushing			Other			Total		
	Stone	Shale	Stone and Shale	Stone	Shale	Stone and Shale	Stone	Shale	Stone and Shale	Stone	Shale	Stone and Shale
A.-Labor; (Man-Hrs per ton)												
Drilling	0.119	0.051	0.111	-	-	-	0.012	0.006	0.012	0.131	0.059	0.123
Blasting	0.017	0.010	0.016	-	-	-	-	-	-	0.017	0.010	0.016
Scaling	0.032	0.020	0.031	-	-	-	0.006	0.002	0.005	0.038	0.023	0.036
Loading;												
(A) Shovels	0.031	-	0.027	-	-	-	0.005	-	0.004	0.036	-	0.031
(B) Hand	0.075	0.329	0.105	-	-	-	-	-	-	0.075	0.329	0.103
Hauling;												
(A) Direct	0.049	0.050	0.050	-	-	-	0.032	0.033	0.032	0.082	0.082	0.083
(B) Track	0.062	0.036	0.058	-	-	-	-	-	-	0.062	0.036	0.058
Miscellaneous	-	-	-	-	-	-	0.025	0.025	0.025	0.025	0.025	0.025
Supt.	0.023	0.024	0.023	-	-	-	-	-	-	0.023	0.024	0.023
Crushing	-	-	-	0.032	0.044	0.033	-	-	-	0.032	0.044	0.033
Total labor	0.408	0.520	0.421	0.032	0.044	0.033	0.080	0.069	0.078	0.520	0.633	0.532
Average tons per man-shift	24.3	19.3	23.8	310.	227.	304.	125	144	129	19.2	15.8	18.7
Labor per cent of total	-	-	-	-	-	-	-	-	-	47.5	72.5	49.6
B.-Power and Supplies												
Explosives, lbs. per ton	-	-	-	-	-	-	--	-	-	.685	.466	.655
Total power, Kw. h. per ton	-	-	-	-	-	-	-	-	-	-	-	2.17
Shovels	-	-	0.41	-	-	-	-	-	-	-	-	.41
Locomotives	-	-	0.70	-	-	-	-	-	-	-	-	.70
Compressors	-	-	0.39	-	-	-	-	-	-	-	-	.39
Dump	-	-	-	-	-	0.02	-	-	-	-	-	.02
Crushers	-	-	-	-	-	0.52	-	-	-	-	-	.52
Screens	-	-	-	-	-	0.06	-	-	-	-	-	.06
Elevators	-	-	-	-	-	0.02	-	-	-	-	-	.02
Conveyors	-	-	-	-	-	0.04	-	-	-	-	-	.04
Washing	-	-	-	-	-	0.01	-	-	-	-	-	.01
Other supplies, per cent of total	-	-	-	-	-	-	-	-	-	-	-	10.7
Supplies and power, per cent of total	-	-	-	-	-	-	-	-	-	-	-	14.1
Per cent of total cost	-	-	-	-	-	-	-	-	-	-	-	78.5

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Table 8. - Detailed summary of costs, January 1st to July 1st, 1930.

	Stone		Shale		Stone and shale	
	Per cent	Cost per ton	Per cent	Cost per ton	Per cent	Cost per ton
Loading:						
Total all shovels	--	$0.045	--	--	--	$0.039
Total all hand-loading	---	.045	--	$0.215	--	.075
Total loading	15.3	.090	36.3	.215	17.5	.104
Drilling:						
Operating labor	--	.098	--	.064	--	.095
Air	--	.010	--	.010	--	.010
Operating supplies	--	.011	--	.012	--	.012
Repair supplies	--	.006	--	.006	--	.006
Total drilling	21.3	.125	15.5	.092	20.6	.122
Blasting:						
Labor	--	.013	--	.007	--	.010
Explosives and other supplies	--	.095	--	.063	--	.092
Total blasting	18.3	.108	11.8	.070	17.2	.102
Haulage:						
Locomotives	--	.043	--	.043	--	.043
Trolley	--	.006	--	.006	--	.006
Cars	--	.011	--	.011	--	.011
Track maintenance	--	.053	--	.063	--	.054
Total haulage	19.1	.113	20.9	.123	19.1	.114
General charges	26.1	.154	15.5	.092	25.6	.151
Grand total	100	.590	100	.592	100	.593

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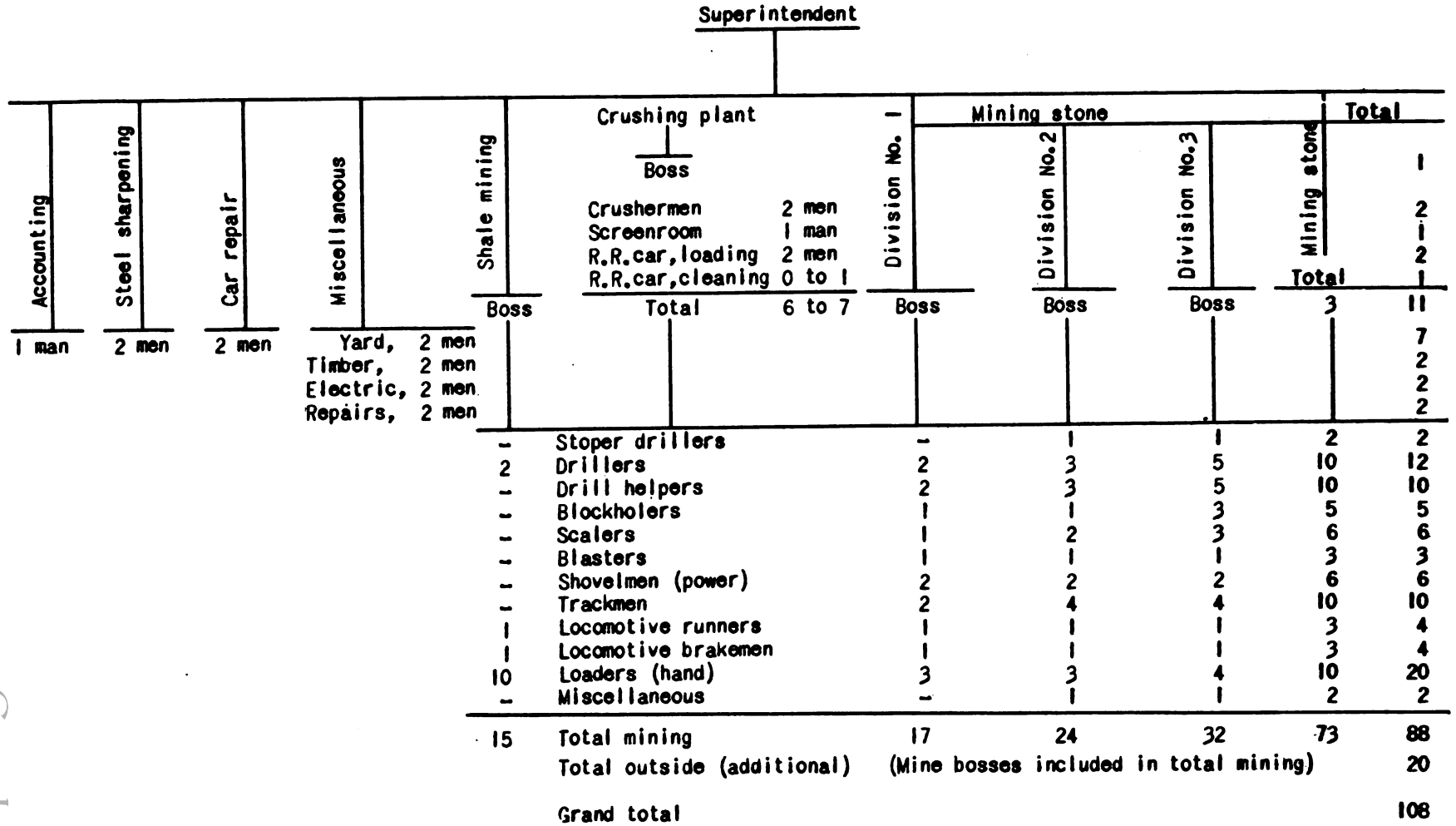

-	Stoper drillers	-	1	1	2	2
2	Drillers	2	3	5	10	12
-	Drill helpers	2	3	5	10	10
-	Blockholers	1	1	3	5	5
-	Scalers	1	2	3	6	6
-	Blasters	1	1	1	3	3
-	Shovelmen (power)	2	2	2	6	6
-	Trackmen	2	4	4	10	10
1	Locomotive runners	1	1	1	3	4
1	Locomotive brakemen	1	1	1	3	4
10	Loaders (hand)	3	3	4	10	20
-	Miscellaneous	-	1	1	2	2
15	Total mining	17	24	32	73	88
	Total outside (additional)	(Mine bosses included in total mining)				20
	Grand total					108

Figure 6.- Organization chart

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